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GAS PLASMA ETCHING METHOD

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Claims

1. A gas plasma etching method, characterized by the following facts: a pair of flat plate electrodes are set parallel to each other in a reaction vessel; the workpiece is placed on the surface of one of the aforementioned electrodes; under a prescribed gas pressure in the aforementioned reaction vessel, a high-frequency electric power is applied between the aforementioned electrodes to generate a gas plasma to etch the aforementioned workpiece; as the aforementioned workpiece, a laminated structure consisting of an underlying layer and a layer for etching formed on the underlying layer is used; at least a portion of the electrode surface at least on the side of setting of the workpiece is made of the same material as that of the aforementioned underlying layer.

2. The gas plasma etching method described in Claim 1, characterized by the fact that the entire surface of the electrode on the side of setting of the workpiece is made of the same material as that of the underlying layer of the workpiece.

3. The gas plasma etching method described in Claim 1, characterized by the fact that another portion of the surface of the electrode on the side of setting of the workpiece is made of the same material as that of the layer for etching of the workpiece.

4. The gas plasma etching method described in any of Claims 1-3, characterized by the fact that the high-voltage side of the high-frequency electric power is connected to the electrode on the side of setting of the workpiece.

5. The gas plasma etching method described in any of Claims 1-4, characterized by the fact that the underlying layer of the

workpiece is made of silicon, and the layer for etching of the workpiece is made of silicon oxide.

Detailed explanation of the invention

This invention pertains to a method for etching a workpiece having a laminated structure by a parallel flat plate gas plasma etching apparatus. This invention also pertains to the apparatus used in this gas plasma etching method.

When etching is performed for silicon oxide film and other materials by gas plasma, a parallel flat plate gas plasma etching apparatus is used because it allows processing with higher precision. The electrodes are made of stainless steel, fused silica glass, aluminum, aluminum oxide, etc. On the other hand, when the layer for etching of a workpiece having a laminated structure is to be etched by gas plasma, it is required that the etching rate range of the layer for etching be large enough for the practical application, and the ratio of this etching rate to the etching rate E(u) of the underlying layer, R(E/U = E(E)/Elu) be large enough. However, in a parallel flat plate gas plasma etching apparatus, usually the peripheral portion of the workpiece is etched faster than the central portion. Consequently, etching usually makes progress from the periphery of the workpiece to the center. As a result, when the etching rate of the underlying layer is high, the peripheral portion of the workpiece is etched more deeply than the central portion, and the damage on the underlying layer becomes significant. This is undesired.

The purpose of this invention is to provide an improvement means to meet the aforementioned requirement on a large ratio R(E/u) in etching of a workpiece having a laminated structure in a

parallel flat plate gas plasma etching apparatus, and to overcome the aforementioned disadvantage of nonuniformity in the etching rate distribution on the workpiece.

In the following, this invention will be explained in more detail with reference to an example using a workpiece having a laminated structure made of a silicon oxide (SiO_2) coating as the layer for etching and silicon (Si) film as the underlying layer.

According to references (Solid State Electronics, Vol. 18, pp. 1146-1147, 1975), etc., in the plasma state of the fluorine compound used in the conventional gas plasma etching operation, such as carbon tetrafluoride (CF_4) gas, dissociation takes place for the fluorine radicals (F^*), carbon trifluoride radicals (CF_3^*), etc. Said fluorine radicals display a high reactivity with Si, and said carbon trifluoride radicals display a high reactivity with SiO_2. Consequently, as the content of the fluorine radicals is reduced by a certain method, the etching rate of Si decreases. Consequently, the etching rate ratio of SiO_2 to Si, $R(SiO_2/Si)$, becomes larger, and selective etching of the SiO_2 coating can be realized.

Under this idea, various methods have been proposed. In one of these methods, the gas plasma of a gas mixture of hydrogen-containing flurorine compound, hydrogen, and fluorine compound gas is used. However, even when these etching gases are used, when etching is performed in a parallel flat plate gas plasma etching apparatus using the aforementioned stainless-steel flat plate electrodes, the etching rate ratio of SiO_2 to Si, $R(SiO_2/Si)$, is still not very large. As a matter of fact, $R(SiO_2/Si)$ = at most only about 10.

However, when the parallel flat plate gas plasma etching apparatus and gas plasma etching method of this invention are

adopted, the etching rate of SiO_2, $E(SiO_2)$, becomes high enough for practical application, and the etching rate ratio of SiO_2 to Si, $R(SiO_2/Si)$, also becomes very large. In addition, improvement is realized with respect to the nonuniformity of the etching rates on the workpiece. In this way, the purpose of this invention can be realized.

In the following, this invention will be explained in more detail with reference to application examples. However, as long as the main points are observed, this invention is not limited to these application examples.

Application Example 1

Polysilicon was used to form upper and lower flat plate electrodes (2) and (3) set inside reaction vessel (1) of a parallel flat plate gas plasma etching apparatus shown as an example in Figure 1. On surface material (5) of said lower electrode (3), workpiece (8) prepared by selectively forming SiO_2 coating (7) on the surface of a Si substrate (6) was placed. After said reaction vessel (1) was evacuated to 0.1 mtorr or lower pressure by vacuum pump (9), CHF_3 gas was fed at a prescribed flow rate through gas feed pipe (10). By an evacuation rate adjusting valve (11) set midway between reaction vessel (1) and vacuum pump (9), the gas pressure inside reaction vessel (1) was adjusted in the range of 20-100 mtorr. The high-voltage side of high-frequency electric power source (12) was connected to lower electrode (3) with workpiece (8) placed on it, and the opposite electrode (upper electrode (2)) was connected to ground. Subsequently, the high-frequency electric power was applied from the side of lower electrode (3), so that said CHF_3 gas was converted to plasma for

etching processing. As a result, the portion of Si substrate (6) exposed on workpiece (8) and the portion of SiO_2 coating (7) on the Si substrate were etched at etching rates on Si etching rate curve (13) and SiO_2 etching rate curve (14) shown in Figure 2, respectively. As an example, the results of etching rate distributions of Si and SiO_2 on a single workpiece (8) obtained under gas pressure of 50 mtorr are shown as etching rate distribution curves (15) and (16) shown in Figure 3.

On the other hand, in the parallel flat plate gas plasma etching apparatus shown in Figure 1, surface materials (4) and (5) of upper and lower electrodes (2) and (3) were changed to aluminum, and the workpiece (8) was etched with CHF_3 gas plasma using the aforementioned method. As a result, Si etching rate curve (17) and SiO_2 etching rate curve (18) shown in Figure 2, as well as Si etching rate curve (19) and SiO_2 etching rate curve (20) shown in Figure 3 were obtained.

As can be seen from the aforementioned results, when polysilicon is used as surface materials (4), (5) of the flat plate electrodes, the etching rate of Si was suppressed, so that the etching rate ratio of SiO_2 to Si, $R(SiO_2/Si)$, becomes very large. Also, the etching rate distribution for each workpiece is also improved as it becomes more uniform.

Application Example 2

In the parallel flat plate gas plasma etching apparatus used in Application Example 1, among upper and lower electrodes (2) and (3) with their surface materials (4) and (5) made of polysilicon, surface material (4) of upper electrode (2) was changed to stainless steel. Subsequently, the same method as that in

Application Example 1 was adopted to perform plasma etching of workpiece (8) by CHF_3 gas. As a result, Si etching rate curve (13) and SiO_2 etching rate curve (14) shown in Figure 2 were obtained. On the other hand, in another test, surface material (5) of lower electrode (3) was also changed to stainless steel. As a result, Si etching rate curve (17) and SiO_2 etching rate curve (18) shown in Figure 2, which are almost identical to [the aforementioned curves], were obtained.

Also, when constitutions illustrated in Figures 4-7 were used, the results obtained are similar to those obtained in Application Example 1. In the constitution shown in Figure 4, a fraction of the portion of the surface of lower electrode (3) not covered by the workpiece is formed from surface material (5) made of silicon. In the constitution shown in Figure 5, a fraction of the portion of the surface of lower electrode (3) not covered by the workpiece is formed from surface material (5) made of silicon, and another fraction is formed from surface material (5a) made of silicon oxide. In the constitution shown in Figure 6, a portion of surface material (5) made of polysilicon in Application Example 1 was changed to surface material (5a) made of silicon oxide. In the constitution shown in Figure 7, the surface of lower electrode (3) is formed from surface material (5a) made of silicon oxide, and a fraction of the portion of surface material (5a) not covered by the workpiece is formed from surface material (5) made of silicon.

Tests of etching were carried out in the same way as in Application Examples 1 and 2, yet surface materials (4) and (5) of upper and lower electrodes (2) and (3) were changed to polysilicon ring and plate prepared by alternately setting polysilicon and fused silica glass; or polysilicon having numerous small holes was set on the fused silica plate. The results obtained in all of

these cases were similar to those obtained in Application Example 1. Also, when tests were performed using the same method as in Application Examples 1 and 2, yet the etching gas was changed to a gas mixture of CF_4 and H_2, the results obtained were similar to those obtained in Application Example 1. When a gas mixture of CF_4 and H_2 was used, the content of H_2 with respect to CF_4 gas is preferably in the range of 5-20%. If the content is 5% or less, the etching rate of Si does not become very low. On the other hand, if the content is 20% or greater, the plasma polymerization reaction is prone to take place, and the reaction product of the plasma polymerization reaction covers the surface of the workpiece, and hampers the etching function by plasma.

The mechanism of the aforementioned phenomenon of decrease in the etching rate of underlying layer (6) is believed to be related to the reaction between the active radicals in the plasma and surface material (5) of the same type as that of underlying layer (6), as this reaction inhibits the reaction with underlying layer (6). Consequently, as long as at least a fraction of surface material (5) is made of the same material as that of underlying layer (6), the same effect can be realized even when operation is performed on workpiece (8) made of another material.

As explained in the above, according to this invention, the same material as that of the underlying layer of the layer for etching [sic; below the layer for etching] is used to form electrode surface material on the side of setting of the workpiece among the flat plate electrodes of the parallel flat plate gas plasma etching apparatus; a gas of hydrogen-containing fluorine compound or a gas mixture of hydrogen and fluorine compound gas is used as the etching gas; a high-frequency electric power is applied from the side of the electrode where the workpiece is set

to generate a plasma for etching processing. In this way, while the etching rate of the layer for etching is maintained high enough for the practical application, the ratio of etching rate between the layer for etching and the underlying layer is increased. Also, it is clear that etching can be carried out uniformly. In the application examples, CHF_3 was used as the hydrogen-containing fluorine gas, and H_2/CF_4 was used as the gas mixture of hydrogen and fluorine compound gas. However, as long as the aforementioned main points are observed, other gases may also be used.

Brief description of the figures

Figure 1 is a schematic diagram illustrating the parallel flat plate gas plasma etching apparatus for illustrating an application example of this invention. Figure 2 is a diagram illustrating the etching rates of Si and SiO_2 versus the gas pressure of CHF_3 when polysilicon and aluminum are used as the surface materials of the upper and lower electrodes, respectively, and CHF_3 gas is used as the etching gas. Figure 3 is a diagram illustrating the distribution of the etching rates of Si and SiO_2 in a single workpiece, when polysilicon and aluminum are used as the surface materials of the upper and lower electrodes, respectively, and the operation gas pressure of CHF_3 is 50 mtorr. Figures 4-7 are diagrams illustrating the constitutions of the other application examples of this invention.

1	Reaction vessel
2,3	Flat plate electrode
4,5	Surface material of flat plate electrode

6	Underlying layer
7	Layer for etching
8	Workpiece
9	Vacuum pump
10	Gas feed pipe
11	Evacuating rate adjusting valve
12	High-frequency electric power source
13,17	Etching rate curve of Si
14,18	Etching rate curve of SiO_2
15,19	Etching rate distribution curve of Si
16,20	Etching rate distribution curve of SiO_2

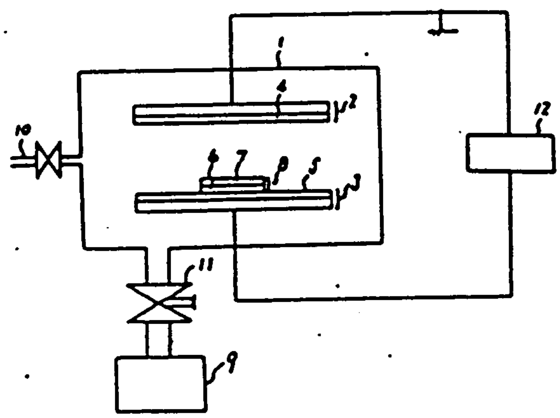

Figure 1

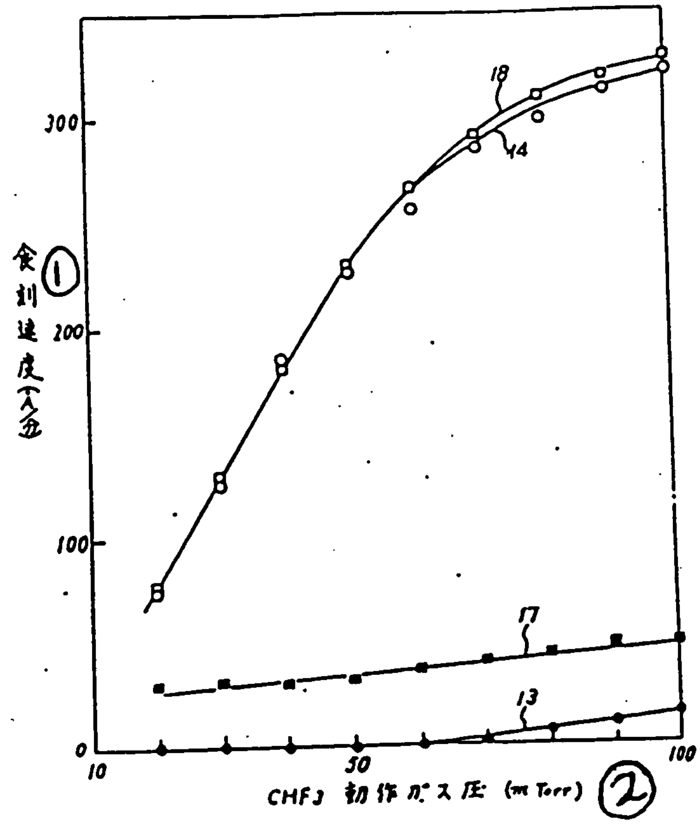

Figure 2

Key: 1 Etching rate (Å/min)
2 Operation gas pressure of CHF_3

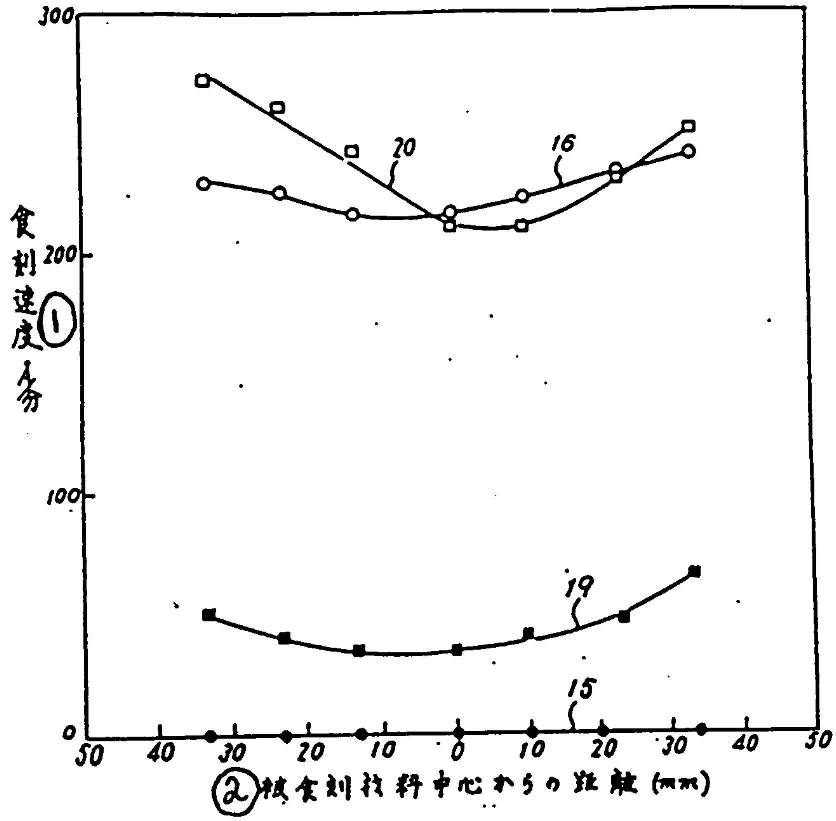

Figure 3

Key: 1 Etching rate (Å/min)
2 Distance from the center of the workpiece

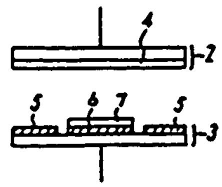

Figure 4

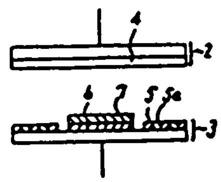

Figure 5

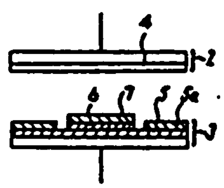

Figure 6

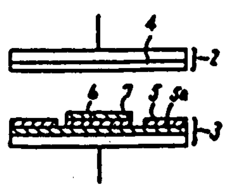

Figure 7